DESCRIPTION

GLASS SUBSTRATE FOR INFORMATION RECORDING MEDIUM
AND METHOD FOR MANUFACTURING THE SAME

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TECHNICAL FIELD

The present invention relates to a glass substrate for
an information recording medium used in a magnetic disc,
10   which is a magnetic recording medium for an information
recording device such as a hard disc, a magneto-optical
disc, and an optical disc or the like, and a method for
manufacturing the same.

15   BACKGROUND ART

Conventionally, a glass substrate for an information
recording medium must have a surface that is as smooth as
possible to enable recording of information with high
20   density. Thus, the surface of the glass substrate is ground
and polished in plural stages during manufacturing to
suppress the formation of microscopic protuberances (refer
to, for example, Japanese Laid-Open Patent Publication No.
11-154325). That is, the glass substrate is ground and
25   polished in steps broadly divided into four steps, rough
grinding, fine grinding, first polishing, and second
polishing. The type of polishing pads, and the grain
diameter and type of polishing agent are appropriately
selected in accordance with the required polishing accuracy.
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A polishing agent supply device for selectively
supplying polishing agents of different types and different
grain diameters to the same polishing device has been

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proposed to change the type or grain diameter of the polishing agent at each polishing step (refer to, for example, Japanese Laid-Open Patent Publication No. 2000-218535). According to such a polishing agent supply device, a plurality of polishing devices do not need to be prepared for each polishing agent that is used. This solves problems, such as that related to installation space.

Recent glass substrates are required to be recordable with higher density. To fulfill this requirement, the smoothness of the glass substrate surface must be improved. In order to improve smoothness of the surface of the glass substrate, the polishing agent must have a finer grain diameter in each polishing step, and the grain diameter of the polishing agent must become finer in a stepped manner as polishing proceeds.

However, when polishing is performed while changing the polishing agent in one polishing device under the above conditions, a problem in which the surface of the glass substrate becomes scratched arises. This is because a polishing agent having a large grain diameter is impregnated in the polishing pad during a preceding polishing step, and the impregnated polishing agent falls out during a subsequent polishing step thereby mixing with the polishing agent having a fine grain diameter. Thus, usage of different types of polishing agents or polishing agents having different grain diameters is impossible in the conventional art, and a plurality of polishing devices must be prepared for each polishing agent when the grain diameter or type is different. Further, when carrying out polishing with a plurality of polishing devices, the task of transferring the glass substrate between each polishing

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device is troublesome and requires a long period of time.

The present invention focuses on the problems existing in the conventional art. It is an object of the present invention to provide a method for manufacturing a glass substrate for an information recording medium capable of using polishing agents of different grain diameters or different types in the same polishing device, while improving production efficiency. A further object is to provide a glass substrate for an information recording medium having high quality to enable recording at a high density.

DISCLOSURE OF THE INVENTION

To achieve the above object, one aspect of the present invention is a method for manufacturing a glass substrate for an information recording medium manufactured by polishing the surface of a raw material glass plate. In the method, the polishing is divided into two steps, a step for performing a first polishing process to roughly polish the surface of the raw material glass plate to be smooth and a step for performing a second polishing process to finely polish the surface of the roughly polished raw material glass plate to be smoother. The second polishing process, which uses a polishing pad made of foam, is divided into two stages, which are pre-polishing with a polishing agent including abrasive grains of cerium oxide and post-polishing with a polishing agent including abrasive grains of silicon oxide. A rinsing process is performed between the pre-polishing and the post-polishing to rinse the raw material glass plate after the pre-polishing with a washing liquid to wash away the abrasive grains collected in the polishing pad

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in pre-polishing during the rinsing process.

It is preferred that the abrasive grains of cerium oxide have a mean grain diameter (D_{50}) of 1.5 μm or less and be smaller than the nap formation hole for the polishing pad.

It is preferred that the abrasive grains of silicon oxide have a grain diameter that is smaller than the grain of the cerium oxide, a mean grain diameter (D_{50}) of less than or equal to 0.2μm, and be smaller than the aperture diameter of the nap formation hole for the polishing pad.

It is preferred that the second polishing process have a total task time of 7 to 45 minutes. It is preferred that the post-polishing have a task time of 1 to 40 minutes.

It is preferred that the rinsing process have a task of 1 to 20 minutes. It is preferred that in the rinsing process, load applied to the raw material glass plate by the polishing pad be lower than that in the pre-polishing. It is preferred that in the rinsing process, load applied to the raw material glass plate by the polishing pad be the same as or lower than that in the post-polishing. It is preferred that load related to the rinsing process be 25 to 70 g/cm^2.

It is preferred that in the glass substrate for an information recording medium obtained from the above manufacturing method, micro waviness height (NRa) of a surface measured by a three-dimensional surface structure analyzing microscope, with a measuring wavelength (λ) set at 0.2 to 1.4 mm, be 0.15 nm or less.

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Another aspect of the present invention provides a polishing device for manufacturing a glass substrate for an information recording medium by polishing a surface of a raw

5   material glass plate. The polishing device includes a polishing pad made of foam. The polishing pad performs raw material glass plate polishing that is divided into two stages, which are pre-polishing with a polishing agent including abrasive grains of cerium oxide and post-polishing

10   with a polishing agent including abrasive grains of silicon oxide. A rinsing process is performed between the pre-polishing and the post-polishing for rinsing the raw material glass plate after the pre-polishing with a washing liquid. The polishing pad includes a nap layer with an

15   inner layer, having a plurality of independent bubbles, and an outer layer formed in its surface, having a plurality of nap formation holes with an extremely fine size compared to the independent bubbles. The nap formation holes open at the surface of the polishing pad so that the abrasive grains

20   collected in the polishing pad in the pre-polishing are washed away during the rinsing process.

It is preferred that the nap formation holes of the polishing pad have a hole diameter of 2 μm or greater and 20

25   μm or less, and a depth of 2 μm or greater and 100 μm or less.

The polishing device further includes a lower polishing plate and an upper polishing plate arranged rotatably about

30   a rotation shaft, and a carrier, arranged between the upper polishing plate and the lower polishing plate, for supporting a plurality of raw material glass plates. The surface of the raw material glass plate is polished by the

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polishing pad by rotating the upper polishing plate and the lower polishing plate in a state in which the polishing pad is attached to the lower polishing plate and the upper polishing plate as necessary.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cutaway perspective view showing part of a batch-type polishing device;

10   Fig. 2 is a schematic view of a cross-section of a polishing pad;

Fig. 3 is a view showing the state of the surface of a raw material glass plate in one example taken with an electron microscope;

15   Fig. 4 is a view showing the state of the cross-section of the raw material glass plate of Fig. 3 taken with the electron microscope;

Fig. 5 is a view showing the state of the surface of the raw material glass plate in a comparative example taken

20   with the electron microscope; and

Fig. 6 is a view showing the state of the cross-section of the raw material glass plate of Fig. 5 taken with the electron microscope.

25   BEST MODE FOR CARRYING OUT THE INVENTION

An embodiment of the present invention will now be described with reference to the drawings.

30   During manufacturing of a glass substrate for an information recording medium, a raw material glass plate is cut out in a disc-shape from a sheet of glass plate. The center of the raw material glass plate includes a circular

hole. The glass substrate is formed by polishing the surface of the raw material glass plate with a polishing device. The glass substrate is formed from a multicomponent glass material, such as soda lime glass, aluminosilicate

5   glass, borosilicate glass, and crystallized glass that are manufactured using a float method, a downdraw method, a redraw method, or a press method. A magnetic film and a protective film made of metals or alloys of cobalt (Co), chromium (Cr), iron (Fe) and the like are formed on the

10   surface of the glass substrate obtained from the raw material glass plate to configure an information recording medium such as a magnetic disc, a magneto-optical disc, and an optical disc.

15   As shown in Fig. 1, a polishing device 41 includes a disc-shaped upper polishing plate 42b and lower polishing plate 42a that are parallel to each other and spaced from each other in the vertical direction. An annular internal gear 43 encircles the upper polishing plate 42b and the

20   lower polishing plate 42a. A rotation shaft 44 projects from the center of the lower polishing plate 42a, and a sun gear 45 is arranged on the peripheral surface at the lower end of the rotation shaft 44. An insertion hole 46 is formed at the center of the upper polishing plate 42b, and

25   the rotation shaft 44 is inserted through the insertion hole 46. The upper polishing plate 42b, the lower polishing plate 42a, the internal gear 43 and the sun gear 45 are driven by a motor or the like so as to be independently rotated. A plurality of carriers 47 is arranged between the

30   lower polishing plate 42a and the upper polishing plate 42b. A plurality of circular holes 48 is formed in the carriers 47. Each circular hole 48 receives a raw material glass plate 31. Further, a gear 49 is formed on the peripheral

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portion of each carrier 47. The gears 49 are meshed with
the internal gear 43 and the sun gear 45.

In the polishing device 41, a polishing pad, which is
formed from synthetic resin foam, is attached to the
surfaces of the lower polishing plate 42a and the upper
polishing plate 42b when necessary. The raw material glass
plate 31 is held between the lower polishing plate 42a and
the upper polishing plate 42b or between a pair of polishing
pads in a state received in a circular hole 48 of the
carrier 47. In this state, polishing agent is supplied from
a supply section (not shown) to the surface of the raw
material glass plate 31 by way of the lower polishing plate
42a, the upper polishing plate 42b, and the polishing pad.
A plurality of supply holes (not shown) extend in the
thickness-wise direction on the lower polishing plate 42a,
the upper polishing plate 42b, and the polishing pads. The
polishing agent is supplied to the supply holes from a
supply section, such as a tank containing the polishing
agent. By rotating the upper polishing plate 42b, the lower
polishing plate 42a, the internal gear 43, and the sun gear
45, each carrier 47 revolves about the rotation shaft 44
while rotating about its axis with the raw material glass
plate 31 contacting the lower polishing plate 42a and the
upper polishing plate 42b or the polishing pads. This
polishes the surface of the raw material glass plate 31.

The method of manufacturing the glass substrate will
now be described.

The glass substrate is manufactured through a disc
processing step, a beveling step, a lapping step, a
polishing step, and a washing step.

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In the disc processing step, a sheet of glass plate is cut using a cutter made of cemented carbide or diamond to form a disc-shaped raw material glass plate having a circular central hole. In the beveling step, inner and outer circumferential surfaces of the raw material glass plate are ground so that the outer diameter and the inner diameter have predetermined dimensions and so that the edges of the inner and outer circumferential surfaces are polished and beveled.

In the lapping step, a lapping process is performed on the raw material glass plate to correct the warp of the entire raw material glass plate. Thus, the raw material glass plate becomes a substantially flat plate. The lapping process, which uses the polishing device 41, is performed by sliding the surface of the raw material glass plate 31 along the lower polishing plate 42a and the upper polishing plate 42b while supplying the polishing agent to grind the surface. Further, for the polishing agent of the lapping process, a slurry of abrasive grains, which are grains of alumina and the like, dispersed in water, which serves as a dispersion medium, is used.

The polishing step, which uses the polishing device 41, is performed in a state in which the polishing pads are attached to the lower polishing plate 42a and the upper polishing plate 42b by sliding the polishing pads along the surface of the raw material glass plate 31. In the polishing step, the sliding of the polishing pads polishes and smoothes the surface of the raw material glass plate. In the washing step, foreign materials, such as polishing agent, polishing powder, and dust on the surface of the raw

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material glass plate subsequent to polishing are washed away with a washing liquid. This manufactures a glass substrate having a smooth surface and high cleanliness.

5   The manufactured glass substrate has a surface roughness Ra of preferably 0.4 nm or less. Further, the waviness height Wa of the surface is preferably 0.5 nm or less. Moreover, the micro waviness height NRa of the surface is preferably 0.15 nm or less. The surface

10   roughness Ra indicates a value measured with an atomic force microscope (AFM). The waviness height Wa of the surface is a value measured with a multifunctional disc interferometer (Optiflat) manufactured by Phase Metrix Corporation by scanning a predetermined region of the surface with white

15   light having a measuring wavelength (λ) between 0.4 to 5.0 mm. The micro waviness height NRa of the surface is a value measured with a three-dimensional surface structure analyzing microscope (New View 200) manufactured by Zygo Corporation by scanning a predetermined region of the

20   surface using white light having a measuring wavelength (λ) between 0.2 to 1.4 mm.

When the surface roughness Ra, the waviness height Wa and the micro waviness height NRa respectively exceed 0.4

25   nm, 0.5 nm, and 0.15 nm, the surface of the glass substrate roughens. Thus, the glass substrate may have lower smoothness and lower quality. When the glass substrate has low quality, the distance between the surface of the information recording medium and the head for reading the

30   information recorded on the information recording medium cannot be shortened. Thus, high-density recording becomes difficult. This is because when the head moves on the information recording medium, deficiencies such as the head

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hitting or being caught in the wavinesss of the surface tend to occur.

In the conventional method for manufacturing the glass substrate, the polishing step is divided mainly into three steps, which include a step for performing a first polishing process, a step for performing a second polishing process, and a step for performing a third polishing step so that the surface roughness Ra, the waviness height Wa, and the micro waviness height NRa of the glass substrate has the above values. In the conventional first polishing process, the surface of the raw material glass plate is roughly polished to improve the waviness height Wa. In the conventional second polishing process, the surface of the raw material glass plate is finely polished to improve the micro waviness height NRa and the surface roughness Ra. In the conventional third polishing process, the surface of the raw material glass plate is ultra-finely polished to further improve the micro waviness height NRa and the surface roughness Ra.

The purpose of each process is to polish the raw material glass plate and thus the same. Therefore, polishing devices having the same structure are used. However, since the improvement subject differs, polishing pads having different hardness is used in the first polishing process and the second polishing process, and polishing agents of different types and different grain diameters are used in the second polishing process and the third polishing process.

In comparison, the polishing step of the present invention is divided into two steps, which include a step

for performing a first polishing process to roughly polish
and smooth the surface of the raw material glass plate and a
step for performing a second polishing process to finely
polish and further smooth the surface of the roughly

5 polished raw material glass plate. That is, one feature of
the present invention is in that the polishing step is
completed by two steps, which are the step for performing
the first polishing process and the step for performing the
second polishing process. When completing the polishing

10 step in two steps, if the conventional third polishing
process is simply omitted, the micro waviness height NRa and
the surface roughness Ra of the manufactured glass substrate
will not achieve the above values. This will lower the
quality. Further, when the conventional second polishing

15 process is simply omitted, the time for ultra-fine polishing
associated with the conventional third polishing process
becomes longer. This is because the polishing amount per
unit time is small during ultra-fine polishing since a
polishing agent having a finer grain size than for fine

20 polishing is used.

It is an object of the present invention to manufacture
a glass substrate that satisfies the values of the surface
roughness Ra, the waviness height Wa, and the micro waviness

25 height NRa while completing the polishing step in two steps.
The first polishing process and the second polishing process
of the present invention will now be described.

The first polishing process is a process of removing

30 defects such as, small warps, wavinesss, chipping, and
cracks in the surface of the raw material glass plate. That
is, such defects are formed within a range of substantially
a constant thickness (depth) from the surface of the raw

material glass plate. Thus, by removing part of the surface
through polishing so that the entire raw material glass
plate has a thickness of a predetermined value, the defects
are also removed. Among the defects, wavinesss are formed
5   in lines on the surface of the glass plate when
manufacturing the glass plate, which is the material of the
raw material glass plate, through the above mentioned float
method and the like and are potentially present in the raw
material glass plate. Therefore, in the first polishing
10   process, among the waviness height Wa, the micro waviness
height NRa, and the surface roughness Ra, the surface
roughness Wa is mainly improved.

In the first polishing process, the removal depth for
15   rough polishing is considered to be important because parts
of the surface including defects is removed from the raw
material glass plate. Since the polishing step is performed
to smooth the surface of the raw material glass plate, a
state in which the surface of the raw material glass plate
20   is rougher after the first polishing process than before the
process would contradict the object of the polishing step.
Therefore, in the first polishing process, to make the
surface of the raw material glass plate smoother than prior
to processing, it is important that the surface of the raw
25   material glass plate not be damaged during rough polishing.
In the first polishing process, a hard polisher having
hardness capable of scraping off the surface of the raw
material glass plate without scratching the surface of the
raw material glass plate is used.
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For such a hard polisher, a rough sponge-like foam made
of a synthetic resin, such as polyurethane or polyester,
having a surface including visible bubbles may be used. The

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JIS A hardness of the hard polisher defined under JIS K6301 is preferably between 65 and 95. Further, the compressive elasticity modulus is preferably between 60 to 95%. It is preferred that the hard polisher be attached to the lower polishing plate 42a and the upper polishing plate 42b so that the compressibility is between 1 and 4%.

If the JIS A hardness is less than 65, the compressive elasticity modulus is less than 60%, or the compressibility is higher than 4%, the hard polisher does not have the desired hardness, and a long period of time is required to reach a certain removal depth. In addition, as the hard polisher deforms during polishing and, particularly, as protuberances and wavinesss form on the surface of the polisher, defects such as wavinesss may be formed on the surface of the raw material glass plate and the surface of the glass plate may not be smoothed. If the JIS A hardness is greater than 95, the compressive elasticity modulus is higher than 80%, or the compressibility is less than 1%, the surface of the raw material glass plate may be damaged by the hard polisher, and the surface condition may roughen.

The second polishing process is a process for scraping off an extremely small part from the surface of the raw material glass plate to correct microscopic defects such as micro-wavinesss and microscopic protuberances present in the surface. Such microscopic defects are mostly formed by polishing traces, such as those made during the lapping process or the first polishing process, and distortions resulting from stress during polishing and the like. The protuberances are evened out and corrected to be smooth by scraping the high portions of micro wavinesss or the ridges of microscopic protuberances. When entirely scraping

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microscopic defects, such as wavinesss, polishing traces formed on the surface of the raw material glass plate when scraping off the microscopic defects may become new defects and increase the microscopic defects. In the second

5   polishing process, among the waviness height Wa, the micro waviness height NRa and the surface roughness Ra, the micro waviness height NRa and the surface roughness Ra are improved.

10   In the second polishing process, the removal depth of fine polishing is not important since the surface of the raw material glass plate is polished and evened so as to become a smooth mirror-finished surface, and scraping off only the upper part of the microscopic defect without damaging the

15   surface of the raw material glass plate is considered important. Thus, in the second polishing process, a soft polisher having softness enabling of polishing without greatly scraping the surface of the raw material glass plate is used as the polishing pad.

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    For such a soft polisher, a fine suede-like foam made of a synthetic resin, such as polyurethane or polyester, having a surface with fine bubbles that are hardly visible is used. The Asker C hardness of the soft polisher defined

25   under Society of Rubber Industry, Japan Standard SRIS-0101, is preferably between 58 and 85. The compressive elasticity modulus is preferably between 58 and 90%. It is preferred that the hard polisher be attached to the lower polishing plate 42a and the upper polishing plate 42b so that the

30   compressibility is between 1 and 5%.

    If the Asker C hardness is less than 58, the compressive elasticity modulus is less than 58%, or the

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compressibility is higher than 5%, the soft polisher may
deform during polishing and, particularly, as protuberances
and wavinesss form on the surface of the polisher, defects
such as micro wavinesss may be formed on the surface of the
5   manufactured glass plate. Further, if the Asker C hardness
is greater than 85, the compressive elasticity modulus is
higher than 90%, or the compressibility is less than 1%, the
surface of the raw material glass plate may be damaged by
the soft polisher, and the manufactured glass substrate may
10   have a rougher surface. The suede-like soft polisher
essentially differs greatly from the sponge-like hard
polisher in hardness and is difficult to compare with the
same criteria. Thus, the hard polisher is represented by
JIS A hardness and the soft polisher is represented by Asker
15   C hardness.

In the second polishing process, the raw material glass
plate is fine polished in two stages of pre-polishing and
post-polishing. This is to polish the raw material glass
20   plate to substantially the same degree as the conventional
third polishing process in the second polishing process.

In the stage of the first half for fine polishing, that
is, in pre-polishing, a slurry, in which grains of cerium
25   oxide serving as abrasive grains are dispersed in water
serving as a dispersion medium, is used as the polishing
agent. The reason cerium oxide is selected as the abrasive
grains of the polishing agent is in that cerium oxide
chemically acts with the glass material and polishes the
30   surface more effectively and efficiently. Further, it is
preferred that abrasive grains having a mean grain diameter
(D_{50}) of 1.5 μm or less be used as the abrasive grain. The
mean grain diameter of the abrasive grain is more preferably

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between 0.2 and 1.5 μm. If the mean grain diameter of the abrasive grains is too large, scratches such as polishing traces may form on the surface of the raw material glass plate during pre-polishing. If the mean grain diameter of

5   the abrasive grains is too small, the polishing amount per unit time is reduced, and the polishing time associated with pre-polishing may be prolonged. Further, in the pre-polishing, the micro waviness height NRa and the surface roughness Ra are improved until about half the value of the

10   first polishing is achieved.

In the last half of the stage of fine polishing, that is, in post-polishing, that in which the abrasive grains having a grain diameter smaller than that used in the pre-

15   polishing are dispersed in water serving as the dispersion medium and made into slurry is used. The grains of silicon oxide such as colloidal silica are used for the abrasive grains. Further, the mean grain diameter (D_{50}) of the abrasive grain is preferably less than or equal to 0.2μm.

20   If D_{50} exceeds 0.2μm, the raw material glass plate becomes damaged in post-polishing, and the desired smoothness is not obtained. In the relevant post-polishing, the micro waviness height NRa and the surface roughness Ra are improved until about half the value of the pre-polishing is

25   achieved.

In the second polishing process, a rinsing process is included between the pre-polishing and the post-polishing. The rinsing process is a process for rinsing the raw

30   material glass plate with a washing liquid after polishing. During pre-polishing, abrasive grains of the polishing agent, fragments of the abrasive grains, and glass powder are attached to the surface of the raw material glass plate.

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If such foreign materials remain on the surface, the foreign materials would damage the raw material glass plate during post-polishing. Thus, there is a need to include the rinsing process to rinse and wash the surface of the raw

5　material glass plate with the washing liquid. The rinsing process is performed by supplying the washing liquid to the polishing device while sliding the raw material glass plate on the soft polisher, and the foreign materials are removed from the surface of the raw material glass plate by the

10　sliding of the soft polisher. Further, for the washing liquid, water, pure water, alcohol such as isopropyl alcohol, electrolytic water obtained through electrolytic processing of aqueous solution of inorganic salt such as alkaline metal salt of sodium chloride and the like, or

15　functional water such as water dissolved with gas is used.

　　In the second polishing process, the pre-polishing, the post-polishing, and the rinsing process are continuously performed, unlike when there are two steps, a first

20　polishing process and a second polishing process, that are intermittently performed. That is, the first polishing and the second polishing process are each assigned with a polishing device since they use different types of polishing pads, and the task of transferring the raw material glass

25　plate between the polishing devices between polishing processes is required. Conversely, the pre-polishing, the post-polishing and the rinsing process are continuously performed in the same polishing device since the same type of polishing pad is used. Thus, the polishing agent used in

30　the pre-polishing and the post-polishing, and the washing liquid used in the rinsing process are selectively supplied from the supply section to the supply holes of the polishing device. At least three types of pipes are connected to the

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supply hole of the polishing device to supply two types of
polishing agents and washing liquid. The two types of
polishing agent and the washing liquid are switched and
supplied to the supply hole by opening and closing valves
5   for the pipes.

When switching the two types of polishing agents and
the washing liquid, the polishing agent impregnated in the
polishing pad during pre-polishing may fall out of the
10   polishing pad during post-polishing and the two types of
polishing agents may mix. To prevent this, the soft
polisher, which serves as the polishing pad, that is used
resists impregnation of polishing agents.

15   As schematically shown in Fig. 2, the soft polisher
includes a base material 11, which is made of a non-woven
cloth or the like, and a nap layer 12, which is superimposed
on the surface of the base material 11. The nap layer 12
has a two-layer structure including an inner layer 14, with
20   a plurality of independent air bubbles, and an outer layer
16, with a plurality of nap formation holes 15 opened at the
surface of the nap layer 12. Each independent air bubble 13
is shaped like a water droplet, in which it expands toward
the inner side of the nap layer 12 and narrows toward the
25   surface of the nap layer 12, and is formed to extend in the
thickness-wise direction of the nap layer 12. Each nap
formation hole 15 has an extremely fine size compared to the
independent air bubbles 13, is shaped like a shallow vase,
and is formed independently without communicating with the
30   independent air bubbles 13.

During the second polishing process, the abrasive
grains of the polishing agent enter the nap formation holes

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15. The abrasive grains polish the surface of the raw
material glass plate while entering and exiting the nap
formation hole 15. In this state, the abrasive grains in
the nap formation holes 15 remain in the nap formation holes

5   15 without going deep into the nap layer 12 since the nap
formation holes 15 are not communicated with the independent
air bubbles 13. The abrasive grains remaining in the nap
formation holes 15 are easily washed out from the nap
formation hole 15 with the washing liquid during the rinsing

10   process and discharged outside. Therefore, the abrasive
grains are prevented from traveling deep into the nap layer
12, and by washing away the abrasive grains in the nap
formation holes 15 during the rinsing process, the polishing
agent used in pre-polishing is prevented from falling out

15   from the nap formation hole 15 during post-polishing.

A polishing pad, referred to as a so-called non-buff
pad, that does not undergo buff polishing in advance is used
as the soft polisher, which includes the nap layer 12 that

20   has a two-layer structure. Buff polishing refers to
polishing in which the surface of the polishing pad made of
foam is roughly scraped with a grind stone or the like.

Normally, a polishing pad made of a foam does not

25   include holes open in the surface in a state immediately
after manufacturing. Buff polishing is performed and part
of the surface layer is scraped to open the independent air
bubbles and form the nap formation holes. That is, when the
part of the outer layer 16 above the broken line in Fig. 2

30   is scraped off, the independent air bubbles 13 open at the
surface of the nap layer 12, and become the nap formation
holes. Therefore, in such a normal polishing pad, the nap
formation holes have large diameters, which differ between

holes, and are deep. More specifically, the diameters are between 20 and 100 μm, and the depth is between 400 and 700 μm.

Conversely, the soft polisher serving as the polishing pad of the second polishing process in the present embodiment is such in which the nap formation holes 15 are formed from microscopic air bubbles in the part that is normally scraped off. Thus, the nap formation holes 15 have a diameter of less than 20 μm and a depth of less than 100 μm. The diameter of the nap formation holes 15 is preferably greater than or equal to 2 μm but less than 20 μm. If the diameter is less than 2 μm, the abrasive grains of the polishing agent do not easily enter the nap formation holes 15. If, on the other hand, the hole diameter is greater than or equal to 20 μm, a large amount of abrasive grains that cannot be washed away during the rinsing process enters the nap formation hole 15. The depth of the nap formation hole 15 is greater than or equal to 2 μm but less than 100 μm. If the depth is less than 2 μm, the abrasive grains of the polishing agent are not easily accommodated in the nap formation holes 15. When the depth exceeds 100 μm, the abrasive grains enter too deeply into the nap formation holes 15 such that they cannot be washed away during the rinsing process.

The soft polisher does not have holes open at the surface in a state immediately after manufacturing. Thus, the surface of the soft polisher must be polished to open the nap formation holes 15 without performing buff polishing. A pad dressing process is performed on the soft polisher in advance after the soft polisher is installed in

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the polishing device but before it is used for polishing. The pad dressing process is a process for polishing only a slight amount of the surface of the polishing pad using a dresser. The dresser may be a pad dresser, formed by electrodepositing diamond abrasive grains on the surface of a base material having a circular-plate shape, or a pellet dresser, formed by embedding diamond pellets in the surface of a base material. Among these dressers, the pad dresser is preferably used in the pad dressing process. This is because the pad dresser has finer abrasive grains compared to the pellet dresser and over-polishing of the surface of the polishing pad can be suppressed.

As described above, the features of the second polishing process of the present invention is in that fine polishing is divided into the two stages of pre-polishing and post-polishing, the rinsing process is included between the pre-polishing and the post-polishing, the polishing agent is switched between the pre-polishing and the post-polishing, and the nap layer 12 having the two-layer structure.

With such features, the second polishing process can be performed using one type of polishing pad and one polishing device while changing the types and grain diameter of the polishing agents during the process. Thus, by changing the types and grain diameter of the polishing agents during the second polishing process while completing the polishing step in the two steps of the first polishing process and the second polishing process, the glass substrate is manufactured so as to satisfy the values of the above surface roughness Ra, the waviness height Wa, and the micro waviness height NRa. Further, in order to reliably satisfy

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the values of the above surface roughness Ra, the waviness height Wa, and the micro waviness height NRa, the manufacturing conditions relating to each of the pre-polishing, the rinsing process and the post-polishing are preferably set as described below.

In the pre-polishing, the load applied to the raw material glass plate by the soft polisher is preferably between 50 and 120 g/cm^2. If the load is less than 50 g/cm^2, the raw material glass plate is not sufficiently finely polished during pre-polishing. In this case, the values of the surface roughness Ra and the micro waviness height NRa of the manufactured glass substrate may become high, or the polishing time associated with the post-polishing must be prolonged to satisfy the values of the surface roughness Ra and the micro waviness height NRa of the glass substrate. If the load exceeds 120 g/cm^2, the surface of the soft polisher may deform, and microscopic defects, such as micro wavinesss, may form on the surface of the raw material glass plate. This may result in deficiencies such as the values of the surface roughness Ra and the micro waviness height NRa becoming high or the raw material glass plate being broken by the load during pre-polishing.

In the post-polishing, the load applied to the raw material glass plate by the soft polisher is preferably between 30 and 100 g/cm^2. If the load is less than 30 g/cm^2, the raw material glass plate is not sufficiently polished in the post-polishing, and the surface roughness Ra, or the micro waviness height NRa of the manufactured glass substrate may not satisfy the desired values. If the load exceeds 100 g/cm^2, the surface of the soft polisher may deform, and microscopic defects, such as micro wavinesss,

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may form on the surface of the raw material glass plate. This may result in deficiencies such as the values of the surface roughness Ra and the micro waviness height NRa becoming high or the raw material glass plate being broken

5   by the load.

In the rinsing process, the load applied to the raw material glass plate by the soft polisher is preferably lower than the load of the pre-polishing. Further, the load

10   is preferably the same or low compared to the load of the post-polishing. More specifically, the load is preferably between 25 and 70 g/cm^2. If the load is less than 25 g/cm^2, foreign materials are not sufficiently removed from the surface of the raw material glass plate or abrasive grains

15   of the polishing agent remains in the nap formation holes 15. If the load exceeds 70 g/cm^2, this may result in deficiencies such as the raw material glass plate being broken by the load during the rinsing process.

20   Among the pre-polishing, the rinsing process, and the post-polishing, the task time for post-polishing is preferably between 1 and 40 minutes. If the task time for post-polishing is less than one minute, the surface of the raw material glass plate is not sufficiently polished. If

25   the task time is longer than 40 minutes, the smoothness of the raw material glass plate will not further improve, and the amount of production would be lowered due to the prolonged task time.

30   Further, the task time of the rinsing process is preferably between 1 and 20 minutes. If the task time of the rinsing process is less than one minute, the polishing agent used in the first polishing process is not

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sufficiently removed, and polishing traces form on the surface of the raw material glass plate at the second polishing process. Even if the task time is longer than 20 minutes, foreign materials and residual polishing agent

5   cannot be further removed, and the amount of production would be lowered due to the prolonged task time.

The total task time of the second polishing process is preferably between 7 and 45 minutes. This is the task time

10   made possible by continuously performing the pre-polishing, the rinsing process, and the post-polishing without the need for exchanging raw material glass plates. In order to have the total task time be less than 7 minutes, at least one of the pre-polishing, the rinsing process, and the post-

15   polishing must have a shorter task time or be omitted. In this case, the surface of the raw material glass plate may not be sufficiently polished or the surface of the raw material glass plate may be damaged. If the total task time is longer than 45 minutes, the task time of at least one of

20   the pre-polishing, the rinsing process, and the post-polishing is too long. If the task time of any one of the pre-polishing, the rinsing process, and the post-polishing is too long, the effect of improvement in smoothness and cleanliness of the surface cannot be expected. Moreover,

25   the longer task time may lower the production efficiency.

The advantages of the above embodiment will now be described.

30   In the method for manufacturing the glass substrate of the embodiment, the second polishing process is carried out by dividing fine polishing into the two stages of pre-polishing and post-polishing. Further, the rinsing process

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is included between the pre-polishing and the post-polishing. Polishing agents of different type and different grain diameters are used for the pre-polishing and the post-polishing. Further, the soft polisher used in the second polishing process includes the nap layer 12 with a two-layer structure and is formed so that the polishing agent is not impregnated deeply in the soft polisher. In the second polishing process, therefore, polishing agents of different grain diameters or different types are used in the same polishing device. This enhances the production efficiency. In order to satisfy the values of the desired surface roughness Ra, the waviness height Wa, and the micro waviness height NRa, a polishing step that conventionally requires up to the third polishing step is completed at the second polishing process. This shortens the manufacturing time and increases the amount of production.

The grains of cerium oxide used in pre-polishing has a mean grain diameter (D_{50}) of 1.5 μm or less. In addition, the grains of silicon oxide used in post-polishing have a mean grain diameter (D_{50}) of 0.2 μm or less. Thus, the number of steps associated with the polishing step is reduced, the manufacturing time is shortened and the amount of production is increased while maintaining the quality of the manufactured glass substrate.

The total task time of the second polishing process is between 7 and 45 minutes. During this period, the task time of the post-polishing is between 1 and 40 minutes, and the task time of the rinsing process is between 1 and 20 minutes. Thus, the task time is shortened while maintaining satisfactory quality of the glass substrate.

In the rinsing process, the load applied to the raw material glass plate by the polishing pad is lower than that for the pre-polishing or the post-polishing. Thus, deficiencies such as scratching and cracking of the raw

5   material glass plate are prevented while foreign materials are removed from the surface of the raw material glass plate in a satisfactory manner.

The surface of the glass substrate manufactured through

10   the above manufacturing method has a micro waviness height NRa of 0.15 nm or less. Thus, the glass substrate has high quality and enables high density recording.

Examples embodying the above embodiment will now be

15   explained.

Observation of Polishing Pad

In example 1 and comparative example 1, the second

20   polishing process was performed using a soft polisher made of polyurethane and having the properties shown in table 1. The processing conditions for the second polishing process were five minutes of the pre-polishing under a load of 80 g/cm^2, five minutes of the rinsing process under a load of

25   60 g/cm^2, and five minutes of the post-polishing under a load of 60 g/cm^2. A soft polisher that had not undergone buff polishing in advance was used for example 1, and a soft polisher that had undergone buff polishing in advance was used for comparative example 1. The NRa of the surface was

30   measured for the raw material glass plate after polishing. The result is shown in table 1. The state of the surface and the cross-section of the soft polisher of example 1 taken by an electron microscope (SEM) are shown in Fig. 3

and Fig. 4. The state of the surface and the cross-section of the polisher of comparative example 1 are shown in Fig. 5 and Fig. 6. The image magnification of the electron microscope related to the surface state shown in Figs. 3 and

5   5 is 100 and the image magnification related to the cross-section shown in Figs. 4 and 6 is 40.

Table 1

		Example 1	Comparative Example 1
Thickness	mm	1.13	1.08
Hardness	Asker-C	74	78
Compressibility	%	2.1	1.5
Compressive Elasticity Modulus	%	71.9	86.7
Hole Diameter	μm	10-40	30-80
Surface Roughness Rmax of Nap Layer	μm	19	35
NRa of Raw material glass plate After Polishing	nm	0.13	0.16

As apparent from Fig. 4, the soft polisher of example 1

10   had a nap layer with a generally two-layer structure. Further, as apparent from Fig. 3, the nap formation holes were densely and generally equally dispersed across the entire surface, and the hole diameters were substantially uniform. In comparison, in the soft polisher of comparative

15   example 1, large independent air bubbles were open in the surface of the nap layer with a generally one-layer structure, as apparent from Fig. 6. As apparent from Fig. 5, the nap formation holes were dispersed across the surface and the hole diameters were not uniform. The micro waviness

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height NRa of the raw material glass plate after polishing

was 0.13 nm in example 1 and 0.16 nm in comparative example

1. From the above results, it was shown that the micro

waviness height NRa was improved by using the soft polisher

5   in which the nap layer had a generally two-layer structure.

Observation of Nap Formation Hole Diameters

In reference examples 1 to 4, the soft polisher of

10   example 1 was used, the hole diameters of the nap formation

holes was changed in each example, and the second polishing

process was performed under the conditions shown in table 2.

The residual value of the polishing agent after the rinsing

process and the surface roughness Ra and the micro waviness

15   height NRa of the raw material glass plate after polishing

were measured for each reference example. The results are

shown in table 2. The residual value of the polishing agent

was calculated in the following way. That is, the

concentration was first changed in various ways for the

20   polishing agent used in pre-polishing, and a standard

solution for each concentration was prepared. Next, for

reference examples 1 to 4, the color of the drainage liquid

during the rinsing process and the color of the standard

liquid were compared, and the concentration of the polishing

25   agent in the drainage liquid of reference examples 1 to 4

was obtained. Then, using reference example 1 as a

criteria, the proportion of the concentration of the

reference examples 2 to 4 with respect to the concentration

of the reference example 1 was calculated as the residual

30   value of the polishing agent.

Table 2

	Hole Diameter of Pad (μm)	Polishing Time (min)			Residual Value of Polishing agent	Quality of Raw material glass plate After Polishing (nm)	
		Pre-Polishing	Rinsing Process	Post-Polishing		NRa	Ra
Reference Example 1	5 - 10	5	5	5	1	0.17	0.31
Reference Example 2	5 - 10	5	10	10	0.3	0.16	0.30
Reference Example 3	30 - 90	5	5	5	10	0.25	0.35
Reference Example 4	30 - 90	5	10	10	4	0.22	0.37

From the results of table 2, the residual value of the polishing agent was less than or equal to 1 and thus small for reference examples 1 and 2 having hole diameters of between 5 and 10 μm, and satisfactory results were also obtained for the surface roughness Ra and the micro waviness height NRa. In comparison, for reference examples 3 and 4 respectively having an aperture diameter of between 30 and 90 μm, the residual values of the polishing agent were 10 and 4 and thus large. Further, the surface roughness Ra and the micro waviness height NRa were higher than reference examples 1 and 2.

From these results, when the hole diameter of the nap formation hole was increased, a large amount of polishing agent remained even when the rinsing process was performed. This shows that the quality of the manufactured glass substrate was affected.

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Observation of Load

     In reference examples 5 to 10, the second polishing
5   process was performed using the soft polisher of example 1
while changing the load for the pre-polishing, the rinsing
process, and the post-polishing as shown in table 3. The
state of each raw material glass plate was visually
observed. The results are shown in table 3.
10

Table 3

	Load (g/cm^2)			State
	Pre-Polishing	Rinsing Process	Post-Polishing	
Reference Example 5	80	60	60	Satisfactory
Reference Example 6	80	50	60	Satisfactory
Reference Example 7	90	60	60	Satisfactory
Reference Example 8	80	90	60	Some Having Processing Cracks
Reference Example 9	80	80	60	Some Having Scratches
Reference Example 10	80	20	60	Some Having Processing Cracks

     From the results of table 3, in reference examples 5 to
7, in which the load of the rinsing process was lower than
15   that of the pre-polishing and the same or lower than the
load of the post-polishing, a visually satisfactory glass
substrate was obtained. In comparison, in reference example

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8, in which the load of the rinsing process was higher than that of pre-polishing and post-polishing, processing cracks were formed in some of the manufactured raw material glass plates. In addition, in reference example 9, in which the load of the rinsing process was the same as that of pre-polishing, scratches were formed in some of the manufactured raw material glass plates. Such results showed that it is preferable that the load of the rinsing process be lower than the load of the pre-polishing and the same or lower than the load of the post-polishing. Further, when the load of the rinsing process is lower than that of the pre-polishing, processing cracks sometimes formed in reference example 10 in which the load was excessively low. This is thought to be because the glass substrate could not be sufficiently pressed by the polishing pad during polishing and thus could not be hold in the carrier. The load of the rinsing process is preferably between 25 and 70 g/cm^2, and more preferably between 50 and 60 g/cm^2.

The present embodiment may be modified and embodied as described below.

A chemical strengthening process may be performed on the raw material glass plate in a step before the polishing step, after the polishing step, or between each polishing step to satisfy impact resistance, vibration resistance, and heat resistance characteristics required for the information recording medium. The chemical strengthening process refers to ion conversion of a monovalent metal ion such as lithium ion and sodium ion contained in the composition of the glass substrate to a monovalent metal ion such as sodium ion and potassium ion having a greater ion radius. Further, it is a method for enabling chemical strengthening by applying

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compression stress on the surface of the glass substrate.
The chemical strengthening method is performed by dipping
the glass substrate over a predetermined time into a
chemical strengthening process liquid in which the chemical
strengthening salt obtained by heating and melting a
chemical strengthening salt.

Examples of chemical strengthening salts include
potassium nitrate, sodium nitrate, silver nitrate used
independently or as a mixture of at least two of the above
materials. The temperature of the chemical strengthening
liquid is a temperature that is preferably lower than the
distortion point of the material used in the glass substrate
by about 50 to 150°C, and more preferably the temperature of
the chemical strengthening process liquid itself is about
300 to 450°C. When the temperature is lower than the
distortion point of the material of the glass substrate by
about 150°C, the glass substrate cannot be sufficiently
subjected to the chemical strengthening process. If the
temperature exceeds a temperature that is lower than the
distortion point of the material of the glass substrate by
about 50°C, the glass substrate may be distorted when
performing the chemical strengthening process on the glass
substrate.

In the above embodiments, the polishing process is
performed using the batch-type polishing device. However,
the polishing device is not limited, and the polishing
process may be performed using a sheet-type polishing device
for polishing glass substrates one at a time.

The lapping step may be omitted as long as the surface
conditions of the raw material glass plate, such as

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roughness, warp, wavinesss, and the like, satisfy the
desired values after the beveling step. In such a case, the
task time is further shortened.